

ASSIGNMENT DISCOVERY ONLINE CURRICULUM

Lesson title:

Constructing Earthquake-Proof Buildings

Grade level:

6-8

Subject area:

Earth Science

Duration:

Three to four class periods

Objectives:

Students will achieve the following objectives:

1. Explore different materials, shapes, and design options that affect the durability of a building
2. Understand how to use models to perform controlled scientific experiments

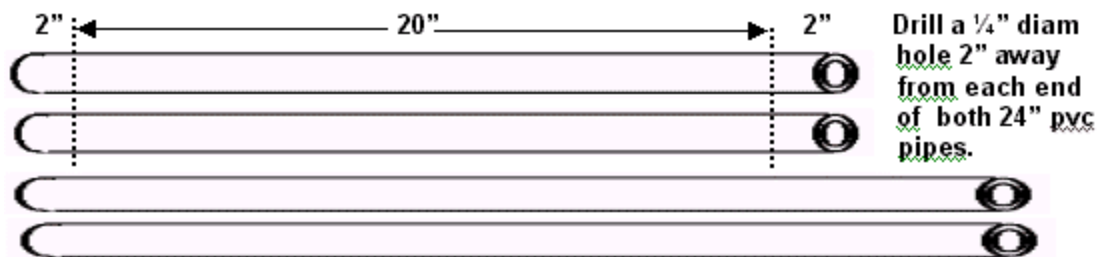
Materials:

For the class:

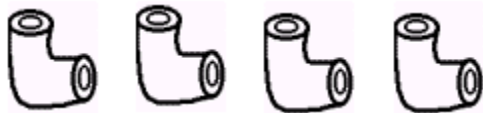
- Computers with Internet access (optional but very helpful)

To build the tabletop earthquake generator, you will need the following:

- A 1-inch _ 10-foot piece of #40 PVC plastic pipe, which will be cut into two 24-inch pipes and two 30-inch pipes



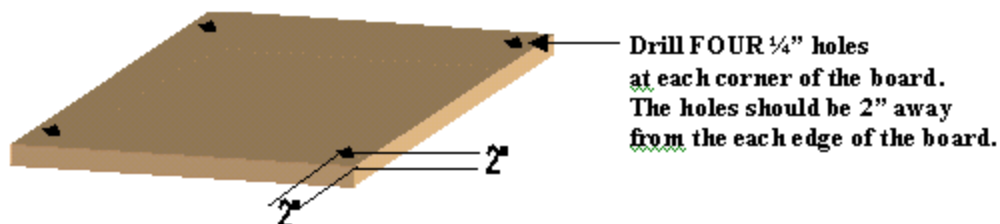
- Four 1-inch #40 PVC 90° degree elbows



- Two _ inch x 36 inch dowels wooden dowels



- One piece of plywood .25 _ 24 _ 24 inches



- Four eyebolts, .25 _ 2.5 inches with .25 inch nuts



- Four hex bolts, .25 _ 1 inch, with .25 inch nuts



- Four rubber bands, #64



- One saw
- One drill with .25-inch drill bit
- Hot glue

To conduct the earthquake experiments, students will need the following:

- Styrofoam packing blocks
- Wood blocks
- Spongy foam
- Cardboard
- Scissors (for cutting the foam board or cardboard)
- Shallow box or pan
- Marbles
- Wood dowels or pencils
- Large sponge
- Sand (optional)
- Teflon cooking sheets (optional)

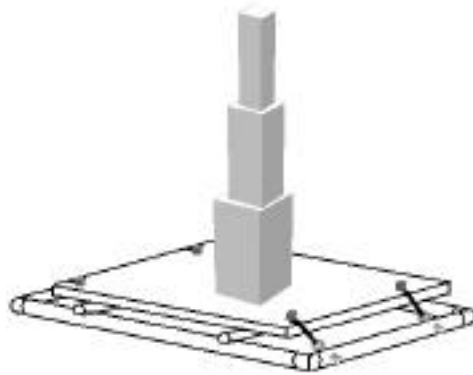
Note: Use either foam or cardboard for the lightweight blocks.

For each student:

- Pencil
- Paper
- One copy of Classroom Activity Sheet: Earthquake Data
- One copy of Take-Home Activity Sheet: Create Your Own Earthquake-Proof Building

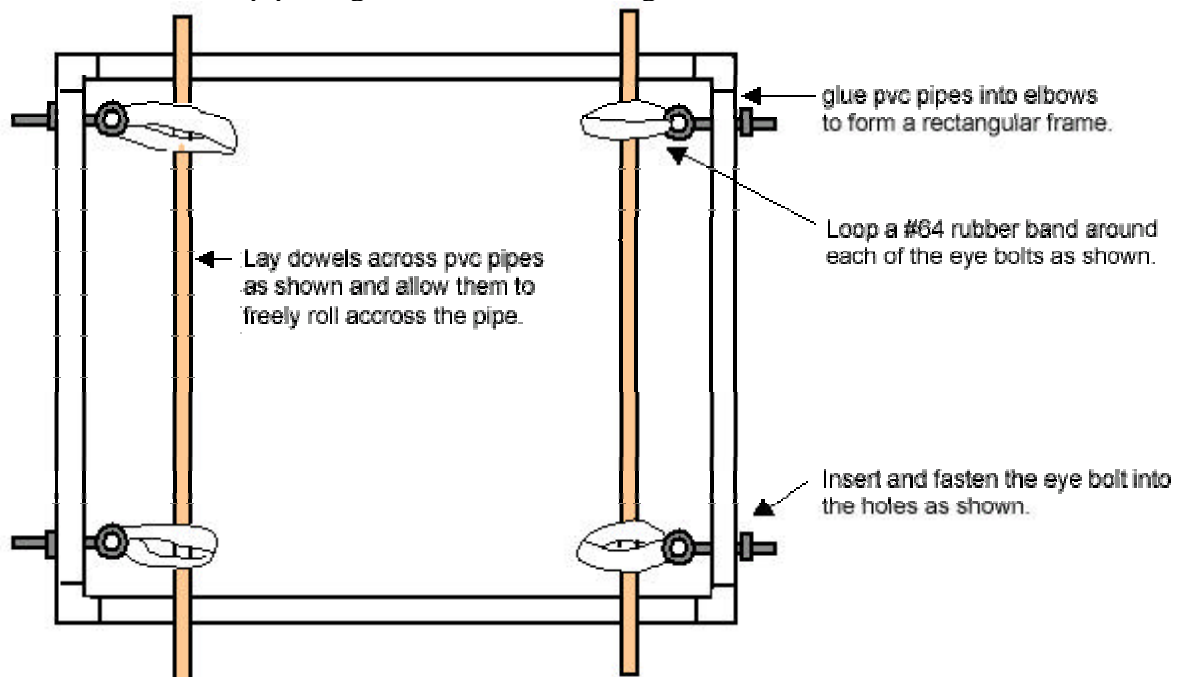
Procedures:

1. Before conducting the experiments, you must build the tabletop earthquake generator.
(Materials for the generator can be found at your local hardware store or a large home supply center.) Consider asking a few interested students to help build the generator, which is shown below with a sample test structure.



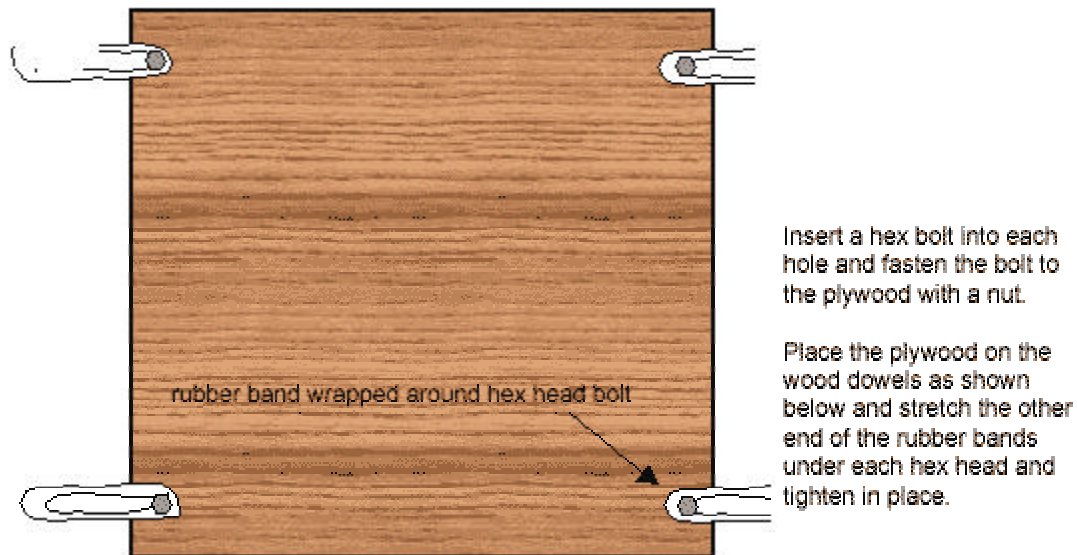
2. Follow the instructions below to assemble the tabletop earthquake generator.

- a. Cut the PVC pipe into two 24-inch pipes and two 30-inch pipes.
- b. Drill a .25-inch hole 2 inches away from each end of both 24-inch PVC pipes.
- c. Glue the PVC pipes together to form a rectangular frame.

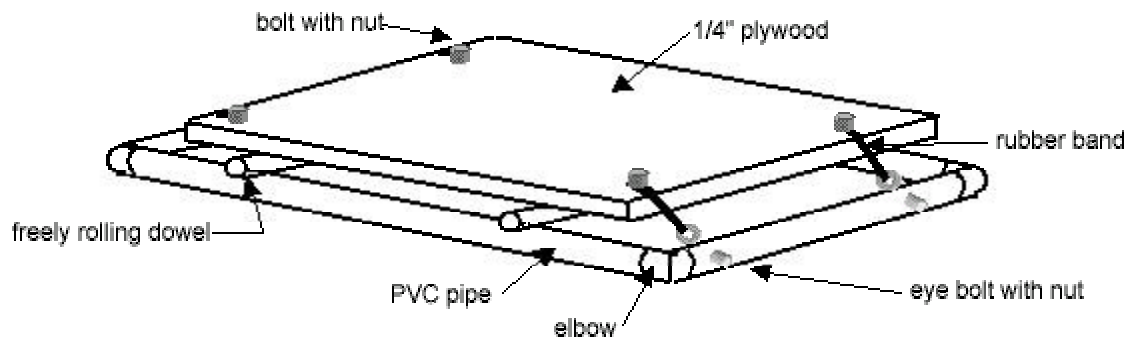


- d. Insert and fasten the eyebolts into the holes.
- e. Loop a rubber band around each of the eyebolts.
- f. Lay the dowels or pencils across the PVC pipe and allow them to roll freely across the pipe.

- g. Drill four .25-inch holes at each corner of the board. The holes should be 2 inches away from the edge of each of the four corners.
- h. Insert a hex bolt into each hole. Fasten the bolt to the plywood with a nut.



- i. Place the plywood on the wood dowels or pencils. Stretch the other end of the rubber bands under each hex head. Tighten the pieces into place.



3. Discuss with the class the different variables that need to be considered when constructing a building durable enough to survive a catastrophic earthquake. Help students understand that the following factors contribute to the durability of a structure:
 - Distribution of weight
 - Variation in shape
 - Variation in height
 - Variation in foundation material
4. Explain to students that they will be constructing their own miniature buildings to test these four factors. Before they begin, have students do some initial research on earthquakes and

earthquake engineering. Encourage them to look for information regarding the four factors that contribute to the durability of a structure. They could begin their research in class and continue as a homework assignment. The Web sites below offer a good starting point for their research:

Discovery Online's "Quake Tech"

http://tlc.discovery.com/tlcpages/greatquakes/greatquakes_tech.html

MCEER—Multidisciplinary Center for Earthquake Engineering Research

<http://mceer.buffalo.edu/education/default.asp>

Earthquake Engineering Research, University of California, Berkeley

<http://www.eerc.berkeley.edu/>

Magnetism to Save Buildings in Earthquakes

<http://www.exn.ca/Templates/Story.cfm?ID=1998091462>

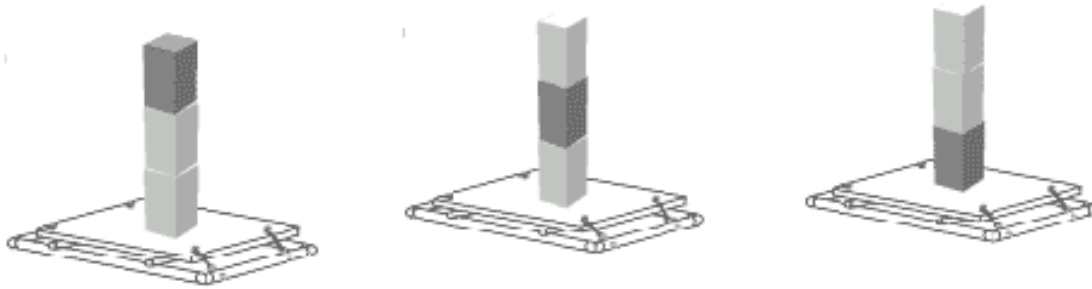
Discovery Online's "Amazing Earth Games—Crumble California"

<http://www.discovery.com/stories/nature/games/quake.html>

5. The next day, divide the class into four groups. Explain that each group will build different structures and then see how durable each is by placing it on the earthquake generator and simulating an earthquake by shaking the generator. Each group will be testing one of the variables discussed above. Before conducting the experiment, each group should make a prediction of which structure has the best chances of surviving an earthquake. Students will record their predictions, observations, and conclusions on the Classroom Activity Sheet: Earthquake Data.
6. Listed below are the variables that will be tested and the steps the groups will follow:

Experimental Group 1: How does the distribution of weight within a structure affect its stability during an earthquake?

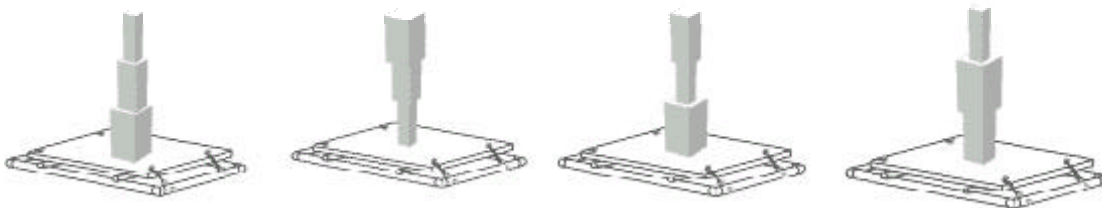
- a. Students in this group will make two rectangular, solid blocks with dimensions approximating 15 _ 15 _ 20 centimeters from light materials such as Styrofoam, cardboard, or foam board. The third block should be made of a heavier material, such as wood. The wood block, placed at different positions during each trial, is the dark-colored block in the drawings below.



- Predict which structure has the best chance of withstanding an earthquake and explain why.
- Place each structure on the earthquake generator and simulate an earthquake by shaking the generator.
- Observe which structure was the most durable and withstood the earthquake.
- Write your conclusion and revise your original explanation if you *disproved* your prediction.

Experimental Group 2: How does variation in shape and placement of objects within a structure affect its stability during an earthquake?

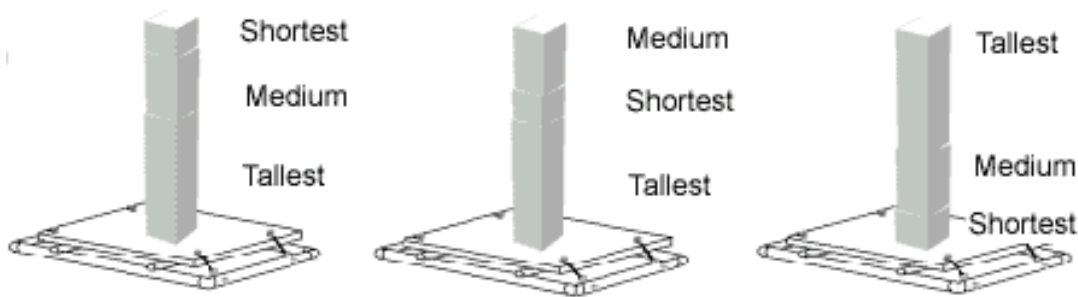
- Students in this group will use three different rectangular, solid blocks made from the *same* material (either Styrofoam, foam board, or cardboard). Make one block 15 _ 15 _ 20 centimeters, one block 10 _ 10 _ 20 centimeters, and one block 5 _ 5 _ 20 centimeters. In each trial, the blocks will be stacked in a different order, as shown in the diagrams below.



- Predict which structure has the best chance of withstanding an earthquake and explain why.
- Place each structure on the earthquake generator and simulate an earthquake by shaking the generator.
- Observe which structure was durable enough to withstand the earthquake.
- Write your conclusion and revise your original explanation if you *disproved* your prediction.

Experimental Group 3: How does the variation in the height of each structural element and its placement affect the structure's stability during an earthquake?

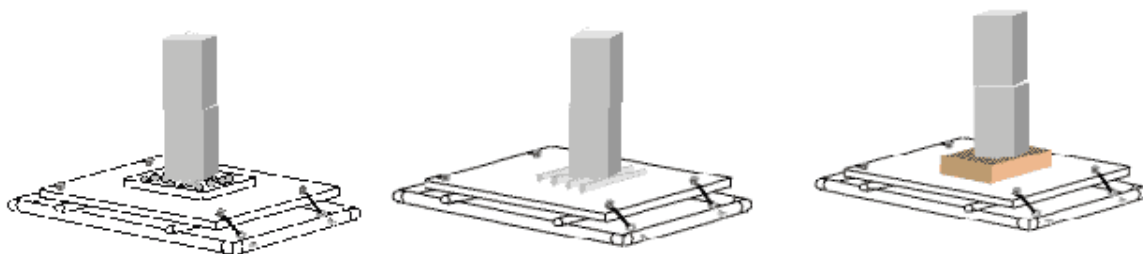
- a. Make three different rectangular, solid blocks out of the *same* material (either Styrofoam, foam board, or cardboard). Make one block 15 _ 15 _ 30 centimeters, one block 15 _ 15 _ 20 centimeters, and one block 15 _ 15 _ 10 centimeters. Have students conduct an earthquake trial in the orders shown in the diagrams below.



- b. Predict which structure has the best chance of withstanding an earthquake and explain why.
- c. Place each structure on the earthquake generator and simulate an earthquake by shaking the generator.
- d. Observe which structure withstood the earthquake.
- e. Write your conclusion and revise your original explanation if you *disproved* your prediction.

Experimental Group 4: How does variation in foundation material affect the stability of a structure during an earthquake?

- a. Make two equal rectangular, solid blocks out of the *same* material. The blocks should have the dimensions 15 _ 15 _ 20 centimeters. In each earthquake trial, the blocks will be stacked in the same way but placed on different foundation materials. In the first trial, put marbles or ball bearings in a shallow box and place the structure on top of the marbles. In trial 2, replace the marbles with several short wooden dowels or round pencils. In trial 3, use a large sponge. (You can try other foundation materials, such as sand or Teflon-coated cooking sheets.)



- b. Predict which structure has the best chance of withstanding an earthquake and explain why.
 - c. Place each structure on the earthquake generator and simulate an earthquake by shaking the generator.
 - d. Observe which structure survived the earthquake the best.
 - e. Write your conclusion and revise your original explanation if you *disproved* your prediction.
7. After students have completed their experiments, have students come back together and share their results. Then assign the Take-Home Activity Sheet: Create Your Own Earthquake-Proof Building. Based on the results of the four experiments, ask each student to construct a tower with three stackable rectangles that would have the best chance of surviving an earthquake. Then have students write a paragraph explaining why their structure is earthquake proof.
 8. During the next class period, have students share their “ideal building” concepts. If time permits, select a couple of “ideal” structures and test them out on the earthquake generator. Can the structures withstand the simulated earthquake?

Adaptations:

Bring in a video camera and have older students videotape a few of the experimental structures built and tested on the earthquake generator. When the videotape is played back in slow motion on a VCR, often it is easier to see why the structure failed. Have students look for the flaws and then correct them by rebuilding the structure. Then they should test the structure again to see if it has become stronger.

Questions:

1. Review the four variables that contribute to the durability of a building: distribution of weight, variation in shape, variation in height, and the type of material used for the foundation. Discuss what is needed to create earthquake-proof buildings. For example, what would happen if a building was constructed properly but was built on a sandy foundation? What issues do builders face when constructing very tall buildings?

2. There have been many severe earthquakes in the 20th century. The 1985 earthquake in Mexico City and the earthquake in Kobe, Japan, in the late 1990s are two examples. Using the Internet or library resources, find out about a serious earthquake. What caused the most damage? What strategies could be implemented so that the damage is not as great the next time?
3. Based on what you have learned about earthquake-proof buildings, in what kind of building would you like to be during an earthquake? Describe its features and why you think it would be safe.
4. One of the largest freestanding domed structures on Earth is the Hagia Sophia in Istanbul, Turkey. It has survived all magnitudes of earthquakes for nearly 1,500 years. Using the Internet or library for research, do a structural analysis of the Hagia Sophia. Then report on some of the theories proposed about why this structure appears to be earthquake proof.
5. Discuss some of the structural features that are being incorporated into modern buildings to help them withstand earthquakes registering on the high end of the Richter scale. Use your library or the Internet to find resources to assist you in your research.
6. Following are three different approaches for preparing for future earthquakes. Discuss the value of each approach. Is one better than the others? Would you be more likely to invest in one approach over the others? Or do you think that all three should be implemented simultaneously? Give evidence to support your ideas.
 - Support and encourage engineers to design better buildings that have a greater chance of withstanding an earthquake.
 - Support and encourage engineers and scientists to learn more about earthquakes, enabling them to better predict when they will take place. This increased knowledge will help people be more prepared when the earthquake does hit.
 - Support public information campaigns that educate people about the safest places to build homes and discourage them from building in areas at the greatest risk for earthquakes.

Evaluation:

Use the following three-point rubric to evaluate students' work during this lesson. Students should be able to work cooperatively in teams, make thoughtful predictions, follow directions to build their structures, perform the experiment, and draw conclusions from the experiment.

Three points: students worked effectively in their groups, made predictions based on sound reasoning, followed directions and built the structures correctly, performed the experiments correctly, and were able to draw conclusions from the experiments.

Two points: students worked somewhat effectively in their groups, made predictions based on somewhat sound reasoning, followed directions and performed the experiments adequately, and were able to draw some conclusions from the experiments.

One point: students had difficulty working in their groups, made predictions that were largely guesses, followed directions but had difficulty performing the experiments, and had difficulty drawing conclusions from the experiments.

Extensions:

Earthquake Competition

Set up a competition and see who can build the tallest freestanding structure that can survive an earthquake on the tabletop earthquake generator. Have students work collaboratively in groups of three or four students. Each group must design and build the structure they test on the earthquake generator. You may choose materials that are convenient to your location and resources, but the structure must comply with the following specifications:

1. The total mass of the structure may not exceed 1.5 kilograms.
2. No element of the structure may be taller than 30 centimeters.
3. The elements of the structure may not interlock or stick together in any way.
4. Glue and other fasteners may be used to hold parts together within the single element height limit of 30 centimeters.
5. The structure must be freestanding. (It may not be stuck in any way to the table.)
6. Any materials may be used as long as they do not violate any other rule.
7. Students may create shock absorbers or include any new idea that is not suggested in the previous activities as long as it does not violate any other rule.
8. Materials may be placed under the structure as long as they do not in any way harm the earthquake generator. These materials are included in the mass limit.
9. Groups should design a way to make sure that the magnitude of the earthquake is constant throughout the competition.
10. The winner is the group that designs the tallest freestanding structure to withstand the highest magnitude earthquake.

Suggested Readings

Secrets of Lost Empires: Reconstructing the Glories of Ages Past

Michael Barnes, et al, Sterling Publishing, 1997.

One of history's greatest mysteries is how ancient civilizations managed to build the structures they did without modern technology. In this book, engineers, architects, archaeologists, stonemasons, and others struggle together to re-create versions of the massive pyramids of Egypt, the earthquake-resistant stonework of the Incas, and several other ancient monuments using only the tools available at the time.

BuckyWorks: Buckminster Fuller's Ideas for Today

J. Baldwin. Wiley, 1996.

R. Buckminster Fuller is probably best known for his development of the amazingly strong and efficient geodesic dome. He called himself a "design scientist," but he was also an architect, a mathematician, an engineer, an inventor, a social visionary, and an author. Written by a colleague of Fuller's, the stories, photographs, and original illustrations present a tantalizing sample of Fuller's lifetime of incredible accomplishments.

Web Links:

Virtual Earthquake

At Virtual Earthquake, learn to locate the epicenter of an earthquake and evaluate its intensity using the Richter Scale.

<http://vcourseware3.calstatela.edu/VirtualEarthquake/VQuakeIntro.html>

Multidisciplinary Center for Earthquake Engineering Research

Looking for a science project on earthquakes? Check this Web site out for ideas on how to design structure that might survive an earthquake.

<http://mceer.buffalo.edu/education/default.asp>

Hagia Sophia

For nearly 1,000 years, Istanbul's great cathedral, the Hagia Sophia, has withstood frequent building-crumbling earthquakes that continue to this day. Did those early architects know something that we don't know today about how to design a large building that can survive an earthquake?

<http://www.exploreturkey.com/hagiasophia/>

Skyscraper CAM

Watch day by day as the tallest structure in Latin America is constructed right in the middle of a major earthquake zone. How are the architects planning to keep this building from collapsing during an inevitable earthquake in or around Mexico City?

<http://www.discovery.com/cams/torremayor/learn.html>

Vocabulary:

center of gravity

Definition: The mathematical point at which the entire weight of a body may be considered as concentrated so that if supported at this point, the body would remain in balance in any position.

Context: Buildings with low centers of gravity are less likely to fall over during an earthquake.

dampen

Definition: To diminish progressively in vibration or oscillation.

Context: The vibration of a building caused by an earthquake may be dampened by placing shock-absorbing materials under and around the foundation of the building.

earthquake

Definition: A shaking or trembling of Earth that is volcanic or tectonic in nature.

Context: When the earthquake stopped shaking our town, only a few buildings that had been designed to withstand earthquakes remained standing.

Richter scale

Definition: A logarithmic scale for expressing the magnitude of an earthquake; for example, 1.5 indicates the smallest disturbance that can be felt, 4.5 indicates a disturbance that can cause slight damage, and 8.5 indicates a very devastating disturbance.

Context: Since the earthquake caused little damage, it probably measured between 3.0 and 5.0 on the Richter scale.

seismology

Definition: The area of science that deals with earthquakes.

Context: Scientists who focus on seismology try to predict when and where earthquakes are going to occur.

Academic Standards:

Grade level:

6-8

Subject area:

Technology

Standard: Identifies appropriate problems for technological design (e.g., identifies a specific need, considers its various aspects, considers criteria for a suitable product).

Benchmark: Designs a solution or product, taking into account needs and constraints (e.g., cost, time, trade-offs, properties of materials, safety, aesthetics).

Grade level:

6-8

Subject area: Technology

Standard: Understands the nature of technological design.

Benchmark: Identifies appropriate problems for technological design (e.g., identifies a specific need, considers its various aspects, considers criteria for a suitable product).

Grade level:

6-8

Subject area: Geography

Standard: Understands how physical systems affect human systems.

Benchmark: Knows the ways in which humans prepare for natural hazards (e.g., earthquake preparedness, constructing houses on stilts in flood-prone areas, designation of hurricane shelters and evacuation routes in hurricane-prone areas).

Credit:

Ted Latham, physics and science and technology teacher, Watchung Hills Regional High School, Warren, New Jersey.

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Earthquake Data

Use this sheet to record your group's experimental question, prediction, observations, and conclusions.

Group's experimental question: _____

Group's prediction: _____

Observations: _____

Conclusions: _____

If the experiment disproved your prediction, write your revised explanation here.



Directions: In class, groups created a series of buildings using blocks of different weights, heights, and shapes, as well as different foundations. Using what you've learned, use three stackable blocks to design a building that has the best chance of withstanding an earthquake. (If you don't have blocks with you, predict which three blocks would create the most durable building.) Keep in mind all the variables discussed during the lesson.
